

10. References

- [1] Lee, W.Y.C.: "Mobile Communications Design Fundamentals", 2nd ed., John Wiley & Sons, New York etc. 1993
- [2] Ketterling, H.-P.: "Some aspects concerning the spectral efficiency of mobile radio transmission systems", CEPT PT SE 23 doc (95)17 rev 3, 1995
- [3] Matra Communication: "Spectral efficiency in PMR or PAMR systems - half duplex effect", CEPT PT SE 23 doc (95)33, 1995
- [4] ETSI:, ETS 300 086 "Technical characteristics and test conditions for radio equipment with an internal or external RF connector intended primarily for speech", Jan 1991
- [5] ETSI:, I-ETS 300 113 "Technical characteristics and test conditions for non-speech and combined analogue speech/non-speech equipment equipment with an internal or external antenna connector for the transmission of data", Jan 1992
- [6] ETSI:, I-ETS 300 219 "Technical characteristics and test conditions for radio equipment transmitting signals to initiate a specific response in the receiver", Oct 1993
- [7] ETSI:, Final Draft prETS 300 392-2 "TETRA V+D - Air Interface", Nov 1995
- [8] ETSI:, Final Draft prETS 300 393-2 "TETRA PDO - Air Interface", 1995
- [9] ETSI:, Draft prETS 300 394-1 "TETRA Conformance testing specification - Part 1: Radio", Jan 1995
- [10] Nix, A.R., Au, T., Chow, Y.C.: "Simulated performance of Pilot-Aided Trellis Coded Modulation in the presence of co-channel Rayleigh AWGN Distortion", CEPT PT SE 23 doc (94)25
- [11] Securicor: "Spectral efficiency of mobile radio systems using analogue linear modulation", CEPT PT SE23 doc(95)36, March 1995
- [12] Matra Communication: "The TETRAPOL standard", CEPT PT SE23 doc(95)48, August 1995
- [13] ITU-R WP8A, "Draft new Recommendation: Spectrum efficient digital land mobile systems for dispatch traffic", ITU-R WP8A doc 8A/TEMP/86-E
- [14] Mobitex specifications for fixed and mobile terminals - 8kbit/s terminal type 3 - LZA 703 1001/06 R1A
- [15] Motorola Mobile Data Division: "DataTAC Networks Reference handbook"
- [16] Motorola Mobile Data Division: "Radio Data Link Access Procedure (RD-LAP)", 30 March 1992
- [17] Commercial Mobile Notices (various)
- [18] Britland D., Wong P.: "Mobile Data Communications Systems", Artech House, 1995
ISBN 0-89006-751-1
- [19] Bosch internal communication

System Parameter	PM 25	PM 20	PM 12	APCO 25	TETRA 25 V+D	TETRA 25 PDO	TETRA 12 V+D [1]	PMR6 [2]
Reference document		4.5		13	7	8	based on 7	based on 7
Frequency band [MHz] [3]	68..87.5, 146..174, BIII, 406..470			-150/450/900	-380/-900 [4]		nya	nya
Tx-Rx separation [MHz] [5]		9.8, 4.6, 10		5/5/45	10	10/45		
Channel separation [kHz]	25	20	12.5	12.5/6.25	25	25	12.5	6.25
Access mode	FDMA	FDMA	FDMA	FDMA	TDMA	Packet	TDMA	-FDMA
No. of channels per carrier	1	1	1	1	4 [6]	1	2 [6]	1
Type of modulation	PM, SC-FSK	FM, PM, SC-FSK	PM, SC-FSK	C4FM/CQPSK	$\pi/4$ -DQPSK	$\pi/4$ -DQPSK	$\pi/4$ -DQPSK	$\pi/4$ -DQPSK
Baseband width [Hz]	300-3000	300-3000	300-2550					
Modulation bandwidth B_m (kHz)	16.0	14.0	10.1		18.0	18.0	9.0	-4.6
Burst length [ms]	-	-	-		14.167	14.167	28.33	56.67
Frame length [ms]	-	-	-		56.67	-	56.67	56.67
Type of code	BCH	BCH	BCH	trellis	16-state RCPC			
Gross bitrate (kbit/s)	≤4.8	≤4.8	≤2.4	---?	36.0	36.0	18.0	8.0
Unprotected bitrate (kbit/s)				9.6?	7.2	-	7.2	<7.0?
Protected bitrate (kbit/s)	≤2.4	≤2.4	≤1.2	6.1	4.8	19.2	4.8	4.8
Code rate					-0.5	-0.5	-0.5	-0.6
Error detection/correction					FEC	FEC	FEC	FEC
Speech Codec [Type/kbit/s]	various	various	various	IMBE/4.4	ACELP 4.6			ACELP 4.6
Codec interleaving depth					0, 1, 4, 8			
Tx RF power, base station [dBm]	≤54	≤54	≤54	≤57	28..46	28..46	≤46?	- ≤46
Tx RF power, mobile [dBm]	≤54	≤54	≤54	40..50	15..45	15..45	≤45?	- ≤45
Tx RF power, handportable [dBm]	≤37	≤37	≤37	30..37	15..35	15..35	15..35	15..35
BS power level control range [dBm]	-	-	-		28..46			
MS power level control range [dBm]	-	-	-		15..45			
Tx spurious emissions [dBm/dBc]	-36/70	-36/70	-36/60		-36/60	-36/60	-36/60	-36/60
Rx sensitivity, static [dBm] (typical/limit)	-119/-107	-117/-107	-114/-107		-112..-115	-112..-115	-115..-118	-118..-121
Rx sensitivity, dynamic [dBm]	--110	--108	--105		-103..-106	-103..-106	-106..-109	-109..-112
C/I, static [dB]	≤8	≤8	≤12		-6..8	-6..8	-6..8	-6..8
C/I, dynamic [dB] [7]	17	17	21		≤19	≤19	≤19	≤19
Adjacent channel rejection, stat. [dB]	≥70	≥70	≥60					
Adjacent channel rejection, dyn. [dB]	-58	-58	-48		≥45	≥45	≥45	≥45
Spurious responses, static [dB/dBm]	70/-37	70/-37	70/-37		-/-45	-/-45	-/-45	-/-45
Rx blocking, static [dBm] at ≥1MHz	-23	-23	-23		-25	-25	-25	-25
Rx dynamic range, static [dBm]	-119..-7 [8]	-117..-7 [8]	-114..-7 [8]		-106..-29	-106..-29	-109..-29	-112..-29
Multipath equalisation [μs]	-	-	-	50	55/110	55/110	55/110	N [9]

Table A1: General Properties of current PMR Systems, APCO 25, TETRA and possible TETRA derivatives

1. dormant 2. proposal 3. differing in Europe 4. Frequency bands for TETRA are still under consideration 5. main cases

6. The number of usable channels per carrier in TDMA systems may be different for Direct Mode operation

nya = not yet allocated

7. (C/I), for analogue systems has been calculated as (C/I)+9dB to account for fading but not shadowing

8. According to FTZ 17 TR 2049

9. not necessary

System Parameter	ASTRO	Cognito	EDACS	MIRS	MOB.II [1]	MODAC. RD-LAP[1]	MPT 1327	SR 440	T-POL	TTIB
Reference document				13	14	16	4,5	19	12	11
Frequency band [MHz]	-160		160/450/900	900	80/160/400/900	410..430	various	80/160/450	-80/450	80/160/BIII
Tx-Rx separation [MHz]			24/20	45	10		various	1..20		1..15
Channel separation [kHz]	25/20/12.5	12.5	12.5/25	25	12.5	12.5	12.5	12.5/25	12.5/10	5
Access mode	FDMA	FDMA	TDMA	TDMA	FDMA	FDMA	FDMA	FDMA	FDMA	FDMA
No. of channels per carrier	1	1	[2]	6 [2]	1	1	1	1	1	1
Type of modulation	QPSK-C		$\pi/4$ -DQPSK	m16QAM [3]	GMSK BT=0.3	4FSK	PM, SC-FSK	CP-BFSK	GMSK	TTIB SSB
Baseband width [Hz]							300..3000			300..3000
Modulation bandwidth B_m [kHz]					10.1?	10.1?	10.1?	10.1/16.0?	10.1/...	3.6
Burst length [ms]				15	37?				20	-
Frame length [ms]				40	907?					-
Type of code				trellis	cyclic					-
Gross bitrate [kbit/s]	9.6		4.8/9.6	64	8	9.6	1.2	4.8	8.0	14.4
Unprotected bitrate [kbit/s]	7.2			-	4.8	4.2		4.0		-
Protected bitrate [kbit/s]				7.2	-2.4	-2.1	-0.6	-2.4	-4.8	7.2/2.4 [4]
Code rate					?					various
Error detection/correction				Y	ARQ			Y		various
Speech Codec [Type/kbit/s]				VSELP/4.2	-		-	IMBE	RPCELP 6.0	-
Codec interleaving depth					-					various
Tx RF power, base station [dBm]	40..46?		47..50	≤51	46	40		33..44	42	44/50
Tx RF power, mobile [dBm]	37..40?		24..43	27..40	40	38		33..44	40	44
Tx RF power, handportable [dBm]			27..37	22..35	33	38		20..37	33	...
BS power level control range [dBm]					Y	Y	-	-		Y
MS power level control range [dBm]					23/33	23/33	-	-	(20/30)	Y
Tx spurious emissions [dBm/dBc]					-44	-44		-36		-36
Rx sensitivity, static [dBm]			-110		-113	-114		-116	-120..-118	-112
Rx sensitivity, dynamic [dBm]						-57dBm		-106	-111..-109	...
C/I, static [dB]		12			12	12	12	8	7	8
C/I, dynamic [dB] [5]		21			21	21	21	17	15	17/12.5 [4]
Adjacent channel rejection, stat. [dB]			70		60	60		?	60/45	50
Adjacent channel rejection, dyn. [dB]								60		...
Spurious responses, static [dBm/dBm]			70		70/-37	70/-37		70		70/-37
Rx blocking, static [dBm] at ≥1MHz					>-23	>-23		-17?		-23
Rx dynamic range, static [dBm]					-113..-0	-114..-0		-116..+4.0?		-120..-10
Multipath equalisation [μs]				40/66	N			?		Y

Table A2: General Properties of current and proposed DPMR systems

1. ETS 300 113 2. The number of usable channels per carrier in TDMA systems may be different for Direct Mode operation 3. m=4

4. For TTIB, speech can be achieved at $(C/I)_s = 17$ dB; data can be achieved at 7.2kbit/s in low interference conditions, however in Table C, η_i (interference case) is calculated using 2.4kbit/s at $(C/I)_s = 12.5$ dB. See ref [10].

5. $(C/I)_s$ for analogue systems has been calculated as $(C/I)_s + 9$ dB to account for fading but not shadowing

Type of System	$(C/I)_s$ [dB]	$(C/I)_s [1]$ [dB]	B_{min} [kHz]	ΔF_c [kHz]	[2] N_A	R_{av}/RTC [kbit/s]
PM 25	8.0	17.0	16.0	25	1	2.4
PM 20	8.0	17.0	14.0	20	1	2.4
PM 12	12.0	21.0	10.1	12.5	1	1.2
TETRA 25 V+D	-	19.0	18.0	25	4	4.8
TETRA 12 V+D	-	19.0	9.0	12.5	2	4.8
PMR 6 V+D	-	19.0	-4.6	6.25	1	4.8
APCO 25 12.5kHz				12.5	1	6.1
APCO 25 6.25kHz				6.25	1	
ASTRO Motorola 25				25	1	
ASTRO Motorola 20				20	1	
ASTRO Motorola 12.5				12.5	1	
EDACS Ericsson 25				25		
EDACS Ericsson 12.5				12.5		
MIRS Motorola				25	6	7.2
MPT 1327	12.0	21.0		12.5	1	-0.6
SR 440 Ascom, Bosch 25	8.0	17.0	16.0?	25	1	2.4
SR 440 Ascom, Bosch 12.5	12?	21.0?	10.1?	12.5	1	
TETRAPOL 12.5kHz	7.0	15.0	10.1?	12.5	1	-4.8
TETRAPOL 10kHz	7.0	15.0	...?	10	1	-4.8
TTIB Securicor [3]	8.0	17.0	3.6	5	1	7.2
TETRA 25 PDO	-	19.0	18.0	25	Packet	19.2
MOBITEX II	12.0	21.0	10.1?	12.5	1	-2.4
MODACOM Motorola	12.0	21.0	10.1?	12.5	1	-2.1
Cognito	12.0	21.0		12.5		

Table B: Parameters of PMR and DPMR systems used in Spectrum Efficiency calculations

1. $(C/I)_s$ for analogue systems has been calculated as $(C/I)_s + 9\text{dB}$ to take into account fading but not shadowing
2. The number of usable channels per carrier in TDMA systems may be different for Direct Mode operation
3. For TTIB, 7.2kbit/s data can be achieved in low interference conditions, however η_i in Table C is calculated using 2.4kbit/s at $(C/I)_s = 12.5\text{dB}$ (in this case $N_c = 3.23$). See reference [10]

Type of System	N_p [RTC / MHz]	η_p [bit/s Hz]	N_c [1]	N_t [MHz · Cell]	η_t [bit/s Hz · Cell]	Category
PM 25	40	0.096	5.85 (7)	6.841	0.016	A (1.0)
PM 20	50	0.120	5.85 (7)	8.551	0.021	A (1.3)
PM 12	80	0.096	9.90 (12)	8.083	0.010	A (1.2)
TETRA 25 V+D	160	0.768	7.61 (9)	21.032	0.101	C (3.1)
TETRA 12 V+D	160	0.768	7.61 (9)	21.032	0.101	C (3.1)
PMR 6 V+D	160	0.768	7.61 (9)	21.032	0.101	C (3.1)
APCO 25 12.5kHz	80	0.488				
APCO 25 6.25kHz	160					
ASTRO Motorola 25	40					
ASTRO Motorola 20	50					
ASTRO Motorola 12.5	80					
EDACS Ericsson 25						
EDACS Ericsson 12.5						
MIRS Motorola	240	1.728				
MPT 1327	80	0.048	9.90 (12)	8.083	0.005	A (1.2)
SR 440 Ascom, Bosch 25	40	0.096	5.85 (7)	6.841	0.016	A (1.0)
SR 440 Ascom, Bosch 12.5	80		9.90 (12)	8.083		A (1.2)
TETRAPOL 12.5kHz	80	0.384	4.49 (7)	17.800	0.085	C (2.6)
TETRAPOL 10kHz	100	0.480	4.49 (7)	22.250	0.107	C (3.3)
TTIB Securicor [2]	200	1.44	5.85 (7)	34.204	0.148	C (5.0)
TETRA 25 PDO	40	0.768	7.61 (9)	5.258	0.101	A (0.8)
MOBITEX II	80	0.192	9.90 (12)	8.083	0.019	A (1.2)
MODACOM Motorola	80	0.168	9.90 (12)	8.083	0.017	A (1.2)
Cognito	80		9.90 (12)	8.083		A (1.2)

Table C: Spectrum Efficiency of selected PMR and DPMR Systems

1. Values in this column in brackets are valid for regular, homogeneous, isotropic, hexagonal cells
2. N_t has been calculated using $(C/I)_s = 17\text{dB}$ (valid for speech), however η_t has been calculated using 2.4kbit/s at $(C/I)_s = 12.5\text{dB}$

All results are based on standards or manufacturers' information supplied to the project team.